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Microorganisms of the Upper Atmosphere

IV. Microorganisms of a Land Air Mass as it Traverses an Ocean

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ABSTRACT

FULTON, JOHN D. (U.S. Air Force School of Aerospace Medicine, Brooks Air Force Base, Tex.). Microorganisms of the upper atmosphere. IV. Microorganisms of a land air mass as it traverses an ocean. Appl. Microbiol. **14**:241–244. 1966.—The viable micropopulation at three altitudes (152, 1,066, and 1,981 meters) of a land air mass as it traversed an ocean was determined. At the low altitude, a consistent pattern of decrease in numbers of land-originating microorganisms with increasing distance from shore was observed. At the higher altitudes, the observed pattern was one of irregularity. At the lower altitude the percentages of bacteria and fungi were approximately equal near the coast, but as distance from the coast increased, fungi predominated over the bacteria at all sampling locations. The greatest number of different genera of both bacteria and fungi were obtained at or near the coast. Fungi of the genera *Alternaria*, *Hormodendron*, *Penicillium*, and *Aspergillus*, and bacteria of the genera *Micrococcus* and *Bacterium* predominated at all altitudes and locations.

Only limited efforts have been made to study the microbial population at altitude over oceans. The single-altitude studies of Meier (5) over the Caribbean Sea, Newman (6) over the Tasman Sea, and Pady and Kelly (8) and Pady and Kapica (7) over the North Atlantic are best known. Most of the available knowledge concerning micropopulations over oceans has been obtained from collections at "deck" or "mast height" levels from surface vessels. The subject was reviewed recently by Gregory (3). To my knowledge, no information is available concerning microbial populations of air masses at multiple altitudes during passage from land to water. It was the purpose of this study to obtain such information.

MATERIALS AND METHODS

Sampling. Sampling instrumentation, techniques, and microbiological processing utilized in this study have been reported by Timmons et al. (9) and Fulton and Mitchell (2).

Three aircraft were maintained in a vertical stack formation at altitudes of 152, 1,066, and 1,981 meters (500, 3,500, and 6,500 ft) above mean terrain altitude. These altitudes are referred to as low, medium, and high, respectively. Sampling was accomplished on three consecutive days, 14 to 16 March. On 14 and 15 March sampling tracks were approximately perpendicular to the general direction of the air mass flow, but on 16 March the tracks were approximately 45° to the general air mass flow. The initial samples taken over land near the coast were considered to be representative of the microorganism population being carried from the land mass out over the Gulf of Mexico. Upon completion of the initial sampling, the aircraft were moved downwind approximately 80 km (50 miles) where a new sampling track was established. Successive sampling was accomplished farther from the shore in a southerly direction for 640 km (400 miles) over the Gulf of Mexico. On the return flight back to land, successive samples were taken approximately parallel to the direction of air mass flow. All sampling was accomplished during the time period 1100 to 1900 hr (24-hr clock). All sampling tracks were approximately 80 km long. The sampling area and the 14 March sampling pattern are shown in Fig. 1.

Meteorology. During the initial 2-day period (14–15 March) of this study, the sampling area was under the influence of a stable high-pressure area centered over northwest Texas, which produced northerly winds over south central Texas and the central area of the Gulf of Mexico. By 16 March the center of the high pressure area had moved in a southeast direction, producing winds over the sampling area with an easterly component. At the time of sampling, on this date, the air mass sampled passed over the land area to the east of New Orleans, La., and out over the Gulf of Mexico from a general northeasterly direction. On the two previous days, the air mass moved from a north to northwest direction over the Houston, Tex., area. The same air mass prevailed, however, throughout the entire 3-day period. Some major variations occurred during the 3-day period in the altitude and numbers of cloud layers, but all three sampling altitudes remained clear throughout each of the sampling periods.

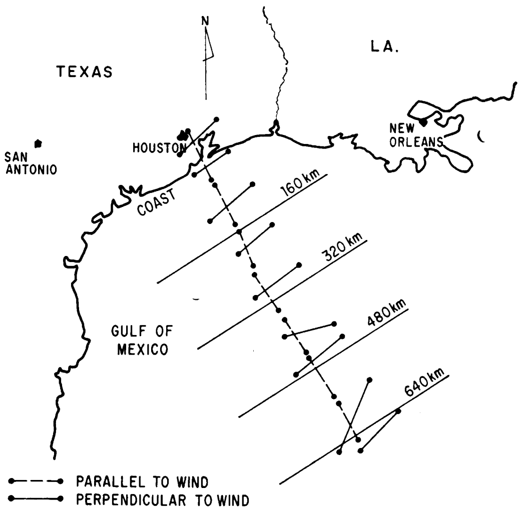

FIG. 1. *14 March sampling pattern.*

RESULTS

The average numbers of microorganisms found at the various altitudes and distances from shore are plotted in Fig. 2. It must be emphasized that samples from which the average micropopulations were determined were not taken at the specified distance but are the average of all samples taken from various locations within the indicated 160-km (100-mile) zone; i.e., the values shown for the 160-km distance were the average of all samples taken from shore to 160 km. The values indicated for the 320-km (200-mile) distance were the average of those samples taken in the region from 160 to 320 km off shore.

At the low altitude (152 meters), a pattern of decrease in micropopulation with increasing distance over the water area was observed. At the middle and high altitude the observed pattern, with one exception, was one of irregularity.

The percentages of bacteria and fungi collected were determined. At the low altitude, bacteria (56%) and fungi (44%) were approximately equal at the coast, with fungi increasing as the distance from the coast increased. At 480 and 640 km, fungi constituted 82% (71 to 100%) of the population. At the middle and high altitudes, at all locations, fungi comprised 76% (65 to 91%) and 82% (73 to 89%), respectively, of the population. These findings contrast with earlier observations made over a land area (1), where bacteria predominated over fungi at the higher altitudes. This difference may have been due to seasonal variation; however, the available data are insufficient to prove this hypothesis. Ten different genera of fungi were found at the low and middle altitudes

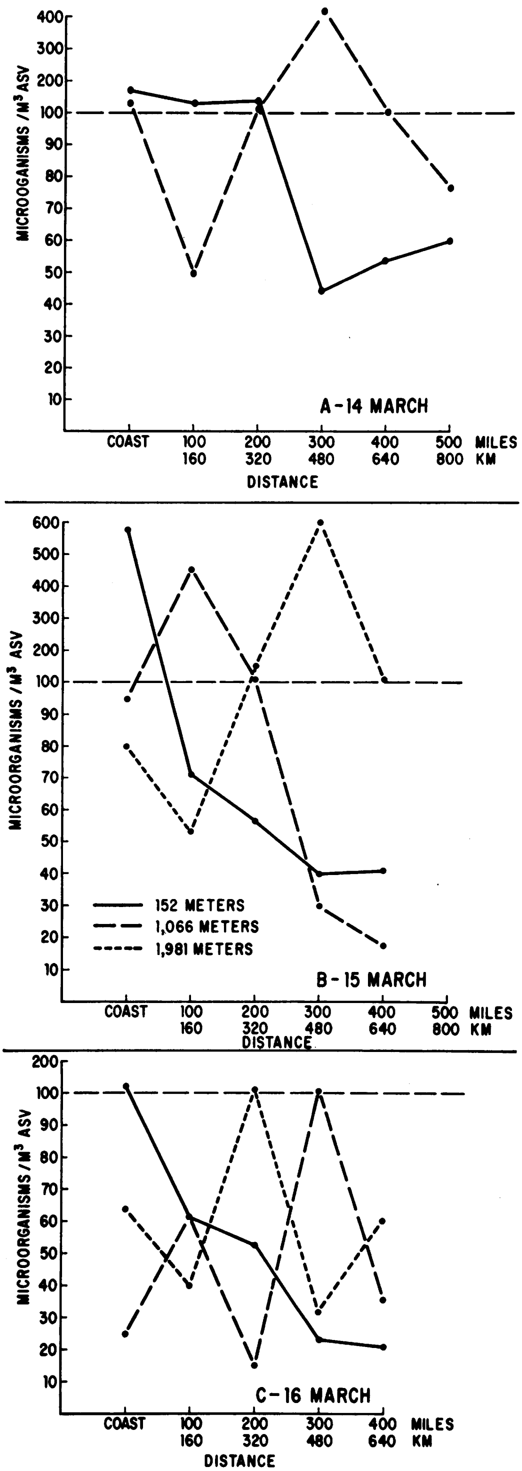

FIG. 2. *Average micropopulations found at each altitude and sampling location.*

near the coast. Only two to six different genera were found at all altitudes and locations over water. *Alternaria* was found at all altitude-location combinations, and *Hormodendron*, *Penicillium*, and *Aspergillus* were found at 11 of 15 possible altitude-location combinations. These four genera accounted for the majority of the fungi collected. Other genera of fungi occasionally found included *Coniothyrium*, *Chaetomella*, *Chaetomium*, *Fusarium*, *Hormodendron*, *Mucor*, *Papularia*, *Phoma*, *Pullularia*, *Rhizopus*, *Stachybotrys*, *Trichoderma*, and *Ustilago*. The predominant bacterial genera found were *Micrococcus*, *Bacillus*, and *Corynebacterium*. *Micrococcus* was found at all 15 altitude-distance combinations, *Bacillus* at 14, *Corynebacterium* at 12, and *Bacterium* at 8. A few actinomycetes were also identified.

DISCUSSION

During passage of an air mass over land, it becomes contaminated with land microorganisms. The extent of contamination is dependent upon the period of time the air mass is over land, the land area, the numbers of microorganisms available, and meteorological and other conditions which would influence dissemination of microorganisms into the air mass and retention therein. The larger particles would have a tendency to "fall out" and be replaced by others, with the smaller particles carried by convective or other meteorological activity to higher altitudes. The process of "fall out" and replacement is continuous over land. "Fall out" occurs over water as well as over land; however, replacement with land microorganisms cannot occur.

As an air mass leaves land and moves over the water, the land microorganism population can remain constant or decrease—it cannot under any condition gain additional land-originating microorganisms. It is possible, however, for the land microorganism population at a given altitude in an air mass to increase by a shift in the microorganisms within the air mass, e.g., "falling out" from higher levels within the air mass or upward migration from lower levels.

The observed low altitude pattern of decreasing population with distance can be adequately explained by "fall out," "wash out," and convective migration to higher altitudes.

It is difficult to explain the fluctuations observed in the micropopulations at the middle and high altitudes. The most likely explanation would be that the high micropopulations may have been collected from regions immediately below the base of an irregular inversion, and the low values were obtained from regions within or above the inversion. Unfortunately, no information was available concerning the location and intensity of inversion layers over the Gulf area at the time of this study. Heise and Heise (4) reported higher concentrations of microorganisms within clouds than in the air above or below the clouds. In this study, clouds were present in the sampling area; however, all samples were taken within the clear. It is doubtful that the presence of clouds would account for the irregularities in micropopulation observed.

It must be emphasized that the same general air mass was studied over the 3-day period; however, the same segment of air within the air mass was not followed. Following the same segment of air as it moves downwind is unquestionably the most direct and effective method of study, but the logistic problems involved dictated the more indirect approach utilized.

On one occasion, the same general segment of air probably was sampled at different locations. The micropopulation of the segment of air that was sampled at the coast on 14 March was high, whereas on 15 March, when it had reached the 480- and 640-km downwind location, the micropopulation was low. This finding indicates that the micropopulation of the same general segment of moving air had been reduced to the same order of magnitude, as shown in the indirect downwind air mass sampling approach.

Reduction in the micropopulation at the low altitude with distance over the ocean and the high micropopulations occasionally observed at the higher altitudes support Gregory's premise (3) that the lower levels of the ocean atmosphere are relatively "purified" of microorganisms by various processes (including sedimentation, contact with the ocean, and rain wash) and that the atmosphere at higher altitudes contains more microorganisms than are found at sea level.

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